***Africa RISING Research Framework***

**Introduction**

Agricultural development and research have often generated a lower impact than expected in Sub-Saharan African countries such as Ethiopia Ghana, Mali, Malawi, Tanzania, and Zambia. Failure of Africa to benefit from long-term research gains has been attributed to several reasons that include:

* incomplete understanding by researchers of farmers’ priorities and strategies;
* weakness of exchange mechanisms among stakeholders (farmers, extension, R&D, etc.);
* blanket recommendations that are often employed without understanding the diversity and context of African farming systems and multi-faceted nature of rural livelihoods;
* dynamic farming systems and highly heterogeneous farming households, decisions, options, and strategies;
* inefficiencies in resource use and poor productivity of smallholder agricultural systems;
* thematic research promoting single technologies or semi-finished research products disregarding most of the components/interactions of households and communities, with limited understanding of farmer ‘demand’ or capacity to adapt and innovate;
* insufficient efforts to integrative research with strong socio-economic components (markets, investment and policies on input systems and access to land right).

**Background**

Tropical regions of rural sub-Saharan Africa (SSA) are characterised by small land holdings of low input rain-fed farming systems. Furthermore, continuous cropping and use of inappropriate farming practices has led to decline in soil fertility, accelerated soil erosion, and degradation of arable lands in SSA. These characteristics adversely impact food security in terms of availability, access, and quality (e.g., Quaye, 2008; Bezner Kerr et al., 2010; Knueppel et al., 2010). This results in a seasonal cycle of food insecurity for cereals (e.g., maize, sorghum, rice, and millet) and for legumes (e.g., common beans, cowpea, groundnut, pigeonpea, and soybeans). Malnutrition is another challenge that most smallholder farming households face in rural tropics. Malnutrition is partly caused by the use of nutrient-poor cereal crops as well as the limited knowledge of the essential nutritional role of legumes by women farmers. To achieve the millennium development goals, the global research and development community as well as some other stakeholders have reached a consensus that productivity of smallholder agriculture in Africa must increase (Andriesse et al., 2007). Several studies across Africa have proven that intensification of smallholder mixed crop-livestock systems is a potential way out of poverty (McIntire et al., 1992; Dixon et al., 2001; De Ridder et al., 2004; IAC, 2004). In some regions of Africa, agroecological intensification has been identified as a promising technology to reduce variability in rain-fed production systems (Myaka et al., 2006; Snapp et al., 2010).

Food security relies not only on high production and access to food but also on the need to address negative effects of current agricultural production systems on ecosystems services (Foreshigt, 2011). This need should also consider the challenge to increase the resilience of production systems to the effects of climate change. In sum, future farming practices must aim at increasing production at farm level while reducing negative environmental (e.g., soil and water) and at the same time increasing contributions to natural capital as well as the flow of environmental services. In other words, practices that enable the sustainable intensification (Pretty et al., 2011) of smallholder farming systems are promoted among smallholder farming households in rural areas to attain the Millennium Development Goal number one – to eradicate extreme poverty and hunger in developing countries.

Sustainable intensification of mixed crop livestock systems is a key pathway towards better food security, improved livelihoods, and a healthy environment. Sustainable intensification can be articulated around 7 components:

* science and farmer inputs into technologies and practices that combine crops–animals with agroecological and agronomic management;
* creation of novel social infrastructure that builds trust among individuals and agencies;
* improvement of farmer knowledge and capacity through the use of farmer field schools and modern information and communication technologies;
* engagement with the private sector for supply of goods and services;
* a focus on women’s educational, microfinance and agricultural technology needs;
* ensuring the availability of microfinance and rural banking; and
* ensuring public sector support for agriculture.

As part of the US government’s Feed the Future initiative to address hunger and food security issues in SSA, the US Agency for International Development (USAID) is supporting the Africa RISING programme to sustainably intensify key smallholder farming systems. Africa RISING comprises three linked multi-stakeholder agricultural research projects in three regions in sub-Saharan Africa. These projects are intended to catalyse concerted research and action by governments and donor agencies around pressing issues. Study areas cover: (i) cereal-based farming systems in the Sudano-Sahelian zone of West Africa (Southern Mali and Northern Ghana); (ii) crop-livestock systems in the Ethiopian highlands; and (ii) maize-based systems in Eastern and Southern Africa (Malawi, Tanzania, and Zambia). This initiative is also a way of bringing regional focus to the CGIAR’s Integrated Systems CRPs 1.1 and 1.2. Feed the Future focuses on reducing poverty and improving nutrition through key investments to improve availability and access to staple food. The goal can be achieved by: (i) enhancing the competitiveness of smallholders in staple crops (e.g., rice, maize, sorghum, and millet), legumes (e.g., cowpea, common beans, cowpea, groundnut, pigeonpea, and soybeans), horticulture, and livestock (e.g., cattle and small ruminants) value chains; (ii) raising productivity through irrigation and rural roads; (iii) improving household nutrition policy reforms; and (iv) developing national capacity for policy, planning and coordination, research and development, as well as monitoring and evaluation (U.S. Government, 2010).

**Purpose**

The programme aims at better targeting R4D at household, community, and landscape levels by enhancing farmers and other stakeholders’ access, assessment, and adoption of promising interventions for sustainable intensification of mixed crop-livestock systems in SSA. The overall goal is to provide pathways out of hunger and poverty for small holder families, particularly for women and children, through sustainably intensified farming systems across varying gradients of market, population density, and agroecological conditions and at different stages of system change and intensification.

**Objectives**

1. Identify, through research, opportunities and constraints to move out of poverty and demand-driven sustainable intensification options that are socially acceptable, economically feasible, and environmentally sound.
2. Combine and adapt these options to address constraints and exploit opportunities for different household categories
3. Evaluate the multiplicability and scalability of innovative SI options beyond research sites.
4. Identify scaling of sustainable farm intensification (institutional innovations, improved market access, and efficiency).

**Outcomes**

1. Farm household typologies (livelihood strategies) and targeting of research solution to intensify farming systems;
2. Sustainable increase of whole farm productivity;
3. Improved on- and off-farm natural resource management;
4. Improved connectivity to and utilization of off-farm systems (e.g., markets, inputs suppliers) that support sustainable intensification;
5. Increased nutritional and economic levels of the target populations, especially women and children;
6. Reduced vulnerability and increased resilience of the target population and farming systems to adverse environmental and economic challenges.

**Research hypotheses**

Our guiding hypothesis is that properly targeted SI practices can provide pathways out of hunger and poverty for smallholder households but must be adapted to specific socio-ecological niches.

Research foci will furthermore address both the demand for and the supply of relevant SI innovations:

1. **Supply side:**
   1. Innovations that have multifunctionality will be more acceptable to farmers, particularly women-headed and resource-poor households;
   2. Innovations that enhance ground cover, will promote resource use efficiency, soil health and more resilient farming systems (stabilizing and increasing yields);
   3. Introduction of legumes into farming systems offers significant opportunities to increase soil health, human nutrition, livestock feed, and household income;
   4. Innovations that integrate high value enterprises (e.g., crops, trees, dual-purpose legumes, or livestock, etc.), into farming systems can increase and stabilize income and reduce hunger gaps of rural poor households;
   5. Appropriate mechanization innovations can raise land and labour productivity and reduce the drudgery of manual labour in smallholder farming.
2. **Demand side**
   1. Adoption and utilization of SI innovation will be enhanced by participatory approaches to better understanding of farmers’ aspirations and constraints;
   2. Provision of supporting services to farmers will reduce the risk and increase the probability of long term adoption of SI innovations;
   3. Promotion of knowledge of nutrition, human, and natural resource management (e.g., soils) can be a driver of SI;
   4. Market value chains can be strong drivers for SI.

**Concepts**

To improve research design at the farm/household and community levels, R4D needs to: (i) be participatory (co-learning and iterative); (ii) consider the diversity of livelihood strategies of households; (iii) include commonly managed natural resources; and (iv) address the sustainability of the overall farm productivity as well as reinforce the resilience of smallholder production systems.

***Participation***

Participation is a fundamental process to better target and to adopt any intervention aiming at improving livelihoods and sustainability of farming systems. In R4D, we need to consider participation as:

* *A capacity building process*: farmers’ decisions and adoption of potential interventions. This means that participation requires improving capacity and a real engagement of stakeholders to identify, test and evaluate potential interventions and risks.
* *A process to generate new knowledge*: research becomes a process of learning by action (Brydon-Miller et al., 2003) with participants engaging in a co-learning and iterative process, bringing together knowledge of different participants (e.g. farmers, development, extension agents, policy-makers, researchers, etc.). Participation also needs to be flexible and adapt to changing biophysical and socio-economic context and needs.
* *A political and interactive process*: participation often includes power relations among participants, facilitators and donors (Cooke and Kothari, 2001). Specifically, interventions dealing with commonly shared resources can potentially generate acute competing claims on these resources, with the poor being most vulnerable to adverse outcomes of such competition. For example, land and water bound resources not merely constitute different – and often conflicting – productive values, but often also represent distinct social-cultural and political values. Communication and negotiation are relevant processes to develop more equitable, management options that reduce rural poverty to sustainably use of natural resources and the resolution of conflicts over them.

***Livelihoods***

‘Being focused on understanding complex local realities, livelihood approaches are an ideal entry point for participatory approaches to inquiry, with negotiated learning between local people and outsiders’ (Scoones, 2009). Agricultural intensification includes either an increasing or using more efficiently capital, labour and other resources, including crop-livestock integration. Furthermore, diversity in livelihoods results from differences in resource endowment and how people apply these resources in pursuance of a living. A relevant approach to conceptualise R4D in agricultural intensification is livelihoods. Specifically, we need to consider:

* *Livelihood strategies*: Given the specific aim of the Africa RISING project, farming systems can be considered in the light of five possible broad household strategies from poverty and hunger. These include: (i) intensification of production; (ii) diversification of agricultural productivities for increased output value; (iii) increased farm size; (iv) expansion in off-farm income; (v) and complete step out of agriculture. I**ntensification** is just one of these five major **livelihood strategies** rural households can make a means of living (Figure 1). Although Africa RISING focuses on intensification, **extensification**, **diversification**, and **migration** need also to be considered when the conditions are adequate as these strategies can influence the overall livelihood and options for intensification. This concept can be used to enhance our understanding of heterogeneous rural livelihoods at pilot study sites. The identification of key rural livelihood types for specific household groups can help identify pathways out of poverty and hence address the issue of system resilience.
* *Drivers and resources*: biophysical and socio-economic **drivers** of farming systems largely influence institutions, major livelihood resources, and promising interventions for a given rural region and farming system. Livelihood **resources** can be classified as natural, economic, human and social capitals. These capitals define the ability of farmers to opt for a certain livelihood strategy, influencing the decision-making of household production orientation.
* *Diversity*: farmers or other stakeholders are neither a homogenous group of actors nor share the same goals or livelihood resources. This diversity has implications not only to set up discussions and R4D process (e.g. dominance or passiveness and equity), but also to better target options (e.g., different challenges and options to different farming systems). At the same time, potential gender imbalances can restrict women’s access to key resources such as land and capital increasing vulnerability. This explicitly requires including diversity within and between farming systems.

Intensification

/extensification

Diversification

Migration

Strategies

Livelihood

Sustainability

Outcomes

Institutions

Resources

Drivers

Figure 1. Conceptual framework (after Scoones, 1998)

* *Institutions*: formal or informal **institutions** such as community regulations and market arrangements (which can also be seen as drivers) can partly influence other drivers and resources, affecting farming challenges and options to intensify and integrate crop-livestock production in a given region. We need to identify and take account for the more relevant institutions that can facilitate or limit the adoption of promising interventions. Local institutions that regulate access right to land by different farmers’ categories need to be addressed with all stakeholders. They can explore alternatives than can contribute to more sustainable and equitable use of natural resources, and where possible, design new technical options and institutional arrangements. These can include access right to land by vulnerable farmers such as widows, etc.
* *Outcomes:* intensification can have **outcomes** related to **livelihoods** including risk and vulnerability (e.g. food security, poverty reduction) and the **sustainability** of the whole system (see below), which can influence drivers, institutions and livelihood resources.

**Sustainability**

Farming systems are a clear example of human-environment interactions. To target interventions to achieve more sustainable intensification and more resilient systems, we need to consider:

* *Integral approach*: sustainability and resilience embodies all: social, economic and environmental dimensions. To better approach sustainability, we need to look at the biophysical and socio-economic components (including livelihood), context and dynamics of farming in the selection and evaluation of promising interventions.
* *Ecosystem services:* changes, trade-offs and synergies between ecosystem services can be key outcomes to assess the sustainability of agricultural intensification.
* *Spatial scales:* dynamics of farming systems and the potential effect of promising interventions occur at different organisational, spatial and temporal scales. Promising interventions need to target farms or communities, which are the targeted scales in Africa RISING. Sill, we might need to include other scales such as intra-household (e.g., gender interactions) and regional levels (e.g., communal resources and ecosystem services).

*Dynamics and pathways:* drivers and farming systems are dynamic, creating potential development pathways of agricultural intensification. We need to account for these pathways to better target interventions and to approach sustainability.

***Interventions***

*Improving natural and social capital*:

Africa RISING is built upon a comprehensive body of research investigating ‘natural’ capital options in Africa. These options include soil fertility, water quality/quantity, crop/livestock/tree spp., agro-biodiversity, and feed resources (Scoones, 1998). Promising interventions are being assessed and inventoried through quick win proposals within this project. Interventions must demonstrate feasibility and have a proven track record in terms of biophysical, social and economic performance. Priority will be assigned to innovations that address rehabilitation of soil health, crop-livestock integration, and resilience to climate change, while simultaneously meeting farmer requirements. Research questions that ARISE will address include 1) how to test promising interventions at multiple scales, household/farm, community and watershed, and over time for variable climate scenarios; and 2) how to integrate the research on natural capital interventions with research on human and social capital, to support improved decision making by farmers, extension educators, NGO and private sector, to building local capacity for adaptation and uptake of interventions.

The different interventions will be implemented following these approaches: (a) addressing the nutritional problem; (b) option for adaptation to climate change in agriculture and natural management; (c) reinforcing the concept/elements of site-specific nutrient management; (d) grain-legumes sequences; and (d) reduce the hunger and income gaps.

*Nutritional problem and/or (hidden hunger):*

Much of the discourse on intensification of food production in Africa has centered on productivity (increasing yield), limited efforts towards achieving minimum nutrient thresholds (intensifying content), particularly in cereal crops. Legume crops and traditional vegetables are also known to represent an important source of food nutrients. Legumes are rich in protein, whereas traditional African vegetables (TAVs) that are rich in micronutrients and other health-promoting phytochemicals can provide an excellent means to complement staples for better nutrition as well as to increase income. The application of these approaches will be site-specific, depending on the agro-ecology, subsequent dominant cereal-based system, as well as farmers’ demand. For example, Zn concentration can be increased in the maize-based systems in Southern Africa through a once off Zn foliar application at grain filling stage. Similarly, traditional African vegetables (TAVs), including Amaranth and African eggplant can be adapted to rice-based cropping systems. It can be grown in association (mixed cropping) during the cereal crop season or in rotation during the fallow season, or as relay crop during the transition periods preceding or succeeding the cereal season. Likewise, multipurpose leguminous species can be adopted as rotational or intercrop technologies with sorghum and millet in the Sudano-Sahelian zones. Common beans, cowpea, groundnut, pigeonpea, and soybean could be potential legume species for consideration. These legumes provide not only nutrient-enrich grains for family food but also supplemental income as well as crop residues for livestock feed. Another option could be the integration of livestock into the cereal-based cropping systems. Livestock make an important contribution to crop production through manure, and at times, traction. Livestock are also a source of cash and protein for household that integrate them with cropping activities.

*Adaptation to climate change in agriculture and natural resource management:*

Climate change assessment data gives no relief to the plight of farming households either, for example, during last 100 yrs. the global mean surface temperature increased by 0.6oC (Lean and Rind, 2009) and projections from 1990 to 2100 shows an increase in global mean annual temperature as ranging from 1.4 to 5.8oC, and this will be accompanied by heat waves and changing precipitation patterns, with most arid and semi-arid areas becoming drier and increasing incidences of floods and droughts (MA, 2005). Changes in rainfall patterns are likely to lead to severe water shortages and/or flooding. These changes could have wide-ranging effects on ecosystems and biodiversity, especially for already fragile ecosystems. For example, aridity index is the long-term average of mean annual precipitation over mean annual evaporative demand, so it follows that water scarcity is an important characteristic of dry land areas. People in dry land Africa depend on maize, sorghum, and millet for staple food. Grain production of these crops is, however, constrained by moisture stress (Dixon et al., 2001). Seasonality of precipitation is known to have dramatic impacts on vegetation life forms, diversity, sensitivity to invasion, and productivity of arid and semi-arid ecosystems. It is widely accepted that livelihoods in African dry lands are a major challenge to attainment of Millennium Development Goal number one – to eradicate extreme poverty and hunger. This challenge renders land-based livelihood households more vulnerable, necessitating practical strategies that can be used to increase the resilience of smallholder production systems at nominal investments. System analysis approaches will be used to quantitatively analyse different options which are within reach of diverse farmer resource endowment categories. Such approach addresses the heterogeneity of local households in an area, whereas considering different adaption options between them. Modelling approaches will be used to address this issue.

**Conceptual and analytical frameworks**

Efforts to move smallholder rural households out of poverty and hunger

To attain the project goal – to provide pathways out of hunger and poverty, it is necessary to identify tailored innovations and to assess the appropriateness of these innovations for diverse households that operate in heterogeneous rural areas. For example, 80% of households’ farmlands in sub-Saharan Africa are less than 2 ha, indicating that land is likely the most limiting non-elastic natural resource. This limitation implies that households with limited land would not improve farm production for food security and income through targeted innovations. To move these households out of poverty, there is a need to employ other strategies beyond farm production as they will not expect significant increases in net returns from targeted innovations. Consequently, there is a need to provide these households with other forms of local safety-net. A conceptual framework is proposed to identify pathways out of poverty and hunger.

**Concept Framework**

A conceptual framework was developed and illustrated in **Figure 2**. It serves as a guide for developing hypotheses to address research objectives. Developed hypotheses can be tested during various research activities in different phases of the project. The conceptual framework for this research on sustainable intensification draws from theories of innovation in agriculture (e.g., Boserup, 1965; Hutchinson, 1957; Pingali et al., 1987). These theories explain changing management systems in terms of changing cultural and socio-economic incentives facing farmers as a result of changing relative factors endowments and education. Additional factors that are important determinants of resource management have been included, inspired by theories of market and institutional development and agricultural household model.

The conceptual framework provides a context to identify and assess key activities to achieve (i) improved household production for food security and income, (ii) improved nutrition; and (iii) improved environmental quality. In targeting interventions to move smallholder households out of hunger and poverty through sustainably intensified agriculture, three main dimensions are considered: intensification, sustainability, and household-level factors. The three dimensions determine opportunities and constraints across terroirs and people and hence across scales (regional, landscape, community, village, and household). Each dimension encompasses key factors that determine strategies in different sustainable trajectories. For example, the dimension on sustainability comprises sustainable indicators at ecosystem and/or field levels such as soil fertility, soil erosion, water availability, and biodiversity (e.g., vegetation species and pests). The sustainability dimension addresses the status and extent of natural resources for a local ecosystem. The household dimension integrates socio-cultural, economic, and institutional factors with potential impact on the use of innovation technologies by individual households and or communities.

|  |  |
| --- | --- |
| **A** | **Annotation**:  Int.: Intensification index  Sust.: Sustainability index  HH: Household  t0: initial time  ti: given time i in the innovation phase  Hht.: Household specific attributes / HH typologies  **B** |
| Figure 2: Theoretical representation of conceptual framework for sustainable intensification pathways: (a): Geographic stratification; (b) theoretical trajectory of specific household in a three-dimensional plane defined by sustainable and intensification indexes and by household systems. | |

This dimension addresses household welfare / wellbeing, gender issues, and household production resources, determining the household’s ability to intensify agricultural production. It further considers the diversity of smallholder households, defining different households’ typologies for targeting innovation. The geographic stratification also determines space of opportunities for and constraints to households operation in heterogeneous rural areas. The conceptual framework, therefore, provides innovation spaces across locations with specific agroecological and market potentials. Each space embodies indicators that can be used to identify strategies in different innovation domains. Identified strategies will then be tested to implement the project at specific locations. The conceptual framework thus provides specific spaces to define pathways for specific households to intensify their current farming systems. Results can be scaled up and out to similar conditions.

To implement the analytical framework, a combination of concepts at terroir, community, and household scales is required?. The implementation will be done in two key steps that interact to provide specific innovation strategies. The first step consists of geographic stratification at region level across locations. The stratification is done in a two-dimension plane, along agricultural potential and market access gradients (**Figure 2 a**). Agricultural potential is determined by agroecological and rainfall factors, whereas market access is related to population density. The two dimensions are often considered across locations in targeting innovations to improve rural livelihoods through agricultural policy, investment in infrastructure, or technology promotion. The geographic stratification is done using geographic information systems (GIS) techniques to map out the locations.

**Sustainability context**

The sustainability context addresses the extent and availability of natural resources such as soils, water availability, and biodiversity (e.g. vegetation and pests). The sustainability context will be addressed at a terroir level that allows us to consider the sustainability at both ecosystems and at farm levels. The ecosystem stratification will help to understand the factors related to sustainability, and the basic sustainability characteristics of the ecosystems for which they are responsible before any intervention. For example, seasonality of precipitation is known to have dramatic impacts on vegetation life forms, diversity, sensitivity to invasion, and productivity of arid and semi-arid ecosystems. It is widely accepted that livelihoods in African semi-arid areas are a major challenge to eradicate extreme poverty and hunger. In these low-potential and remote areas, adoption of input-intensive food crop production may be risky and of limited profitability in rain-fed conditions. The mosaic of crop growth conditions, caused by the spatial variation in rainfall, different crop varieties, landscape potions, and soil types can be explored to produce food crops. By making use these differences in crop growth conditions the risk of production loss in such a semi-arid area can be reduced. Several studies in the West African Sahel showed that physiographic differences at farm and village level are used for diverse agricultural production. A proper disaggregation of cropping areas in semi-arid areas can facilitate targeting of appropriate technologies to reduce the vulnerability of local households to rainfall variability.

The stratification offers opportunity to consider the different landscape positions within which fields can fall. Landscape positions include lower lowlands, upper lowlands, and uplands. Lower lowlands are important for reducing the vulnerability of crop farmers to drought in semi-arid areas. Access to lower lowland fields enhances the capacity of farmers to cope with erratic rain conditions experienced in the semi-arid areas.

In more remote low-potential areas with low population density, improvement of extensive livestock production may offer development potential. Achieving this potential may require the strengthening of collective action institutions to encourage investments in improvements of grazing lands. Planting and managing fodder grasses and trees can improve fodder availability and quality. Manure from the livestock can also be used to increase dryland cereals (sorghum and millet) crop production, especially in the lowlands.

The farm stratification within the terroir will be done to distinguish different fields within and between farms. The farm stratification will help to address the heterogeneity in African smallholder farming systems. Whereas large monocultures are often restricted to large-scale agriculture with a higher management intensity, ‘managed diversity’ is key feature of many smallholder systems. In managing the diversity, crop-based farmers spread their cropping across landscape positions as a way to spread risk posed by drought and flood, or as a way to diversify their cropping systems. The farm stratification will therefore help locate different fields within a given landscape position.

**Strategies**

Different pathways to SI can be supported through research addressing the following:

* + - 1. Overall, the SI ‘best bet options’ or interventions will only be adopted by farmers if they improve yields or enhance yield stability, and improve profitability and increase returns to management, capital, labour, land and natural resources (in both the short and long terms).
      2. To be sustainable, the SI best bets will need to use resources efficiently and conserve the resource base

Specifically, we hypothesize that:

1a. Multifunctionality of innovations will be most appreciated by women farmers, and poor resourced households, in areas with limited market access – acceptance will be highest in quadrats C and D - see Figure 3 below.

High Market Access

‘Quadrat A’ ‘Quadrat B’

Quality soils

Degraded

Soils

‘Quadrat C’ ‘Quadrat D’

Low

Market

Access

Figure 3: Schematic representation of SI pathways along different soil gradients and market opportunities

1b. Innovations that enhance ground cover will build soils, and most effectively if they extend photosynthesis and biological N fixation through diversification with a leguminous grain crop, shrub or tree. Acceptance will be highest in quadrats A and C.

1c. To reduce income gaps interventions will involve adoption of high value products from crops, trees or livestock that require support from innovation platforms and/or market value chains. Acceptance will be highest in quadrats A and B.

1d. To reduce hunger and nutrition gaps, adoption of high value crops and/or integration of livestock (improved breed) is not enough, investment is also required in education on nutrition, and participatory research to support farmer experimentation.

**Implementation**

To combine and implement these concepts in R4D at farm, landscape, and community scales in Africa RISING, a conceptual framework that shows how the project will achieve improved production for food security and income, improved nutrition, and improved environmental quality and how they are interlinked is presented. A list of activities that can be undertaken is presented in Table 1.

Table 1 Hypotheses about innovation strategies in different development domains along agricultural potential and market access gradients at regional level.

|  |  |  |
| --- | --- | --- |
| **Agricultural potential** | **Market potential** | |
| High | Low |
| High | Market value chains for high value perishable commodities:  Packaging, storage, and processing of perishable cash crops, livestock products (milk and eggs), and fruits;  Nutrition-enrich cereals;  Mechanization of intensified systems | Non perishable cash crops  Intensive food crop production  Livestock production;  Improve market infrastructure |
|  | Improved livestock feed availability and quality |  |
|  | Nutrient-limited systems (bring nutrients) |  |
|  | Degraded land |  |
|  | Improve manure handling and storage | Integration of livestock into farming systems |
|  | Appropriate mechanization of smallholder farming systems for high-land resource-endowed but labour constrained households | Test the performance of crops extensive low-external-input cereals |
|  |  |  |
| Low | With irrigation: | With irrigation investment: |
|  | Intensive food crop production | Intensive food crop production |
|  | Perishable cash crops |  |
|  | Dairy, intensive livestock | Without irrigation investment: |
|  | Without irrigation investment | Low external input cereals |
|  | Low-external-input cereals | Extensive livestock production |
|  | Rural off/farm development | Woodlots/forestry |
|  | Investment in water rainfall water harvesting techniques; | Emigration |
|  |  | Other form of local safety-net for land constrained households in low potential agricultural and remote areas |

**Approaches and tools**

The targeting of intervention within a R4D cycle can be supported by using different tools. Along the **entire cycle**, participatory approaches are essential to bring together farmers and other stakeholders in farm and community level such as: 1) participatory resource mapping at the farm or community level to support environmentally sound decision-making, improved resource use efficiency and more profitable production; 2) participatory action research on ‘best bet’ or ‘plausible’ SI options through mother-baby trials, farmer research groups or related participatory methods (Snapp et al., 2010); 3) Landscape-scale participatory research linked to modelling and decision tool development, to support farmers making decisions within a rapidly changing and complex environment. Discussions following these approaches can be supported by using tools such as games, participatory planning, and modelling and scenario development.

The targeting of intervention within a R4D cycle can be supported by using different tools (Table 2). Along the **entire cycle**, participatory approaches are essential to bring together farmers and other stakeholders in farm and community level such as: 1) participatory resource mapping at the farm or community level to support environmentally sound decision-making, improved resource use efficiency and more profitable production; 2) participatory action research on ‘best bet’ or ‘plausible’ SI options through mother-baby trials, farmer research groups or related participatory methods (Snapp et al., 2010). 3) Landscape-scale participatory research linked to modelling and decision tool development, to support farmers making decisions within a rapidly changing and complex environment. Discussions following these approaches can be supported by using tools such as games, participatory planning, modelling and scenario development.

Table 2. Potential areas of intervention for each capital—livelihood resources (after Scoones, 1998).

|  |  |  |  |
| --- | --- | --- | --- |
| **Capitals** | | | |
| **Natural1** | **Economic** | **Human** | **Social2** |
| Soil fertility | Microfinance | Information | Cooperatives |
| Water quality/quantity | Banking | Education | Innovation platforms |
| Crop/livestock/tree spp. | Insurance | Nutrition & health | Value chains |
| Agro-biodiversity | Income | Gender |  |
| Feed resources | Machinery | Labour |  |

Notes: 1 closely related to ecosystem services; 2 directly linked to institutions.

For **problem definition** and improvement in the **selection of promising interventions** by farmers, participatory approaches together with quick assessment tools such as literature review, surveys and other tools (e.g. FEAST) can be used to describe the context and define the major problems in the farming community including potential equity issues (e.g. power and gender). This includes the use of functional typologies that allow participants to simplify the diversity of farmers, as well as to facilitate the targeting of promising interventions for different farming systems.

For the **on-farm and community trials,** experimentation could be pursued through implementing randomized-design intervention and extension programs, to test the effectiveness of different approaches, and quantify farmer demand. For example, randomized selection of participants in a voucher program could be used to test extension methods (provide information versus providing decision tools), or to document farmer perceptions of – and demand for – sustainable intensification interventions. Detailed description described below.

To **evaluate interventions** at farm and community level, we need to assess their influence on intensification and crop-livestock integration. Additionally, we need to look at how these interventions will influence livelihoods and ecosystem services. To achieve this different indicators at different scales are needed; some selected by the participants, others linked to the M&E of Africa RISING.

**Research on scaling out approaches**

Experimentation to understand farmer demand and adoption of SI pathways, at a broader scale, will be pursued through implementing randomized-design intervention and extension programs. We will conduct research on scaling out as we scale out the interventions we are testing in the Africa RISING project. Thus, we will test the effectiveness of different approaches to promoting innovation, adoption of technologies, and quantifying farmer demand.

One approach proposed by Dr Rusike is a voucher program that evaluates the effectiveness of different types of information provided to randomized selections of participants in the voucher program. Thousands of farmers will have access to interventions such as inputs, combined with limited or extensive information in the form of educational messages. Other sets of randomly selected farmers will receive vouchers that combined inputs with access to decision tools such as test kits to promote farmer experimentation. Follow up surveys will document farmer perceptions of – and demand for – the interventions, and evaluate the impact of the extension method on the demand. Similar tests of effectiveness of extension methods linked to vouchers or educational campaigns can be conducted in combination with different interventions across the Africa RISING countries.

Another approach proposed by Dr Snapp is an intensive study in Malawi, comparing two hypothesized drivers of sustainable intensification, market opportunities and nutrition opportunities (Bezner Kerr et al., 2007). Participatory extension and research will be focused on sustainable agricultural interventions linked to either expanding market access, or improved knowledge of nutrition. This is based on research in Malawi that has shown widespread adoption among smallholders in communities where nutrition education was integrated fully with education on agrobiodiversity and legume production technologies. Likewise, market development linked to extension of sustainable production technologies has been shown to be successful. In this study we propose to randomly select communities to be exposed to either a participatory, community nutrition approach, or a participatory, market-value chain approach, or even their combinations. Control areas where communities are not exposed to either intervention approach will also be monitored. Research can thus be designed to test approaches, and quantify drivers of sustainable intensification; at the same time as natural resource improving interventions are tested for biological performance, and farmer assessment.

Development interventions that explicitly or implicitly employ a value chain approach will be explored. Emphasis will be placed on interventions that reflect upon gender issues as these can assist women in producing value-added products that contribute to improving equity and health through: (i) increased income and (ii) improved knowledge on food selection and use. The approach acknowledges that men are sometimes left out of value chains, but the approach focuses on issues related to the impact of values chains interventions on women, and the exposure nutritional educational through capacity building to access the impact of capacity building on household health.

Stratification and identification of SI trajectories:

The combination of GIS and remote sensing techniques will be employed for the stratification done at terroir level (see Table 3). In addition, statistical analysis that include clustering techniques will be used on survey households and field data to relate the identified fields in the different landscape positions to specific households. It will further help to address the sustainability issue at field/farm level, whereby assessing the soil fertility status of identified fields within and between farms. This approach has the capability to identify different classes of soil fertility that can be used to evaluate the level of soil responsiveness in terms of ‘response’, ‘intermediate’ and ‘non-responsive’ fields within the farm.

Table 3: Stratification for sustainability done for specific geographic location

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | **Agricultural potential and Market access** | | | |
|  | | **Lo-Lo** | **Lo-Hi** | **Hi-Lo** | **Hi-Hi** |
| Sf/E | Lo | Lo-Lo-Lo | Lo-Lo-Hi | Lo-Hi-Lo | Lo-Hi-Hi |
|  | Hi | Hi-Lo-Lo | Hi-Lo-Hi | Hi-Hi-Lo | Hi-Hi-Hi |
|  |  | **Lo-Lo** | **Lo-Hi** | **Hi-Lo** | **Hi-Hi** |
| WA | Lo | Lo-Lo-Lo | Lo-Lo-Hi | Lo-Hi-Lo | Lo-Hi-Hi |
|  | Hi | Hi-Lo-Lo | Hi-Lo-Hi | Hi-Hi-Lo | Hi-Hi-Hi |
|  |  | **Lo-Lo** | **Lo-Hi** | **Hi-Lo** | **Hi-Hi** |
| Biod. | Lo | Lo-Lo-Lo | Lo-Lo-Hi | Lo-Hi-Lo | Lo-Hi-Hi |
|  | Hi | Hi-Lo-Lo | Hi-Lo-Hi | Hi-Hi-Lo | Hi-Hi-Hi |

Sf/E: Soil fertility / Erosion

WA: Water availability

Biod.: Biodiversity

**Household specific attributes / Typologies**

Farms are heterogeneous and complex, – variability within and between farms may lead to failure of promising technologies in terms of boosting productivity and long-term sustainability. The complex farms are further managed by heterogeneous farmers who make management decisions at household level. Innovative efforts to improve the poor productivity of smallholder agricultural systems must be designed to target socially diverse and spatially heterogeneous farm systems.

The diversity of smallholder farming systems is related to the variability in production resource (e.g. land, labour, livestock, etc.) endowment status and production objectives of individual farm household. This variability is shaped by differences in access to off/non farm opportunities and hence livelihood strategies and food security, land resources, markets, education, and other institutions. The heterogeneity in smallholder farming systems demands the tailoring of innovations to suit local biophysical conditions and socio-economic circumstances. For achieve better uptake of these innovations, it is key to take into account the heterogeneity of rural households in an area, as adaption options differ strongly between them. The formulation of household typologies creates windows of opportunities to meet the needs of each type of household.

Household typologies will be developed in parallel with the terroir stratification. The methodology of the typology formulation is articulated using the first step of the DEED approach by Tittonell (2007). This approach helps to define representative prototypes of fields, cropping sequences, farms or localities that capture key management, socio-economic, and agro-ecological aspects of systems under study. Their heterogeneity and diversity at different scales will be categorised, relying on solid understanding of key drivers of such variability and using methodologies that allow comparisons across systems. A combined data driven and expert-knowledge method will be used to categorise households into functional farm types. Principal component analysis (PCA) and information gained from the stratification will inform the choice of criteria for household categorisation. Households will then be grouped into homogeneous classes using simple classification methods developed around the stratification hypotheses. Socio-economic data on household assets will be used to define household categories within specific strata and to define intensification options (Figure 4). For example, the combination of variables on farm size and labour informs on the low potential for land and labour constrained households to increase their farm productivity. Depending of the geographic location of this group of households, other options can be targeted to move them out poverty.



Figure 4: Schematic representation of the use of stratification to develop household typology.

**Analytical framework**

The conceptual framework provides an analytical framework for the research implementation. Gs (geographic strata) x Sustainability x Ht (Household type) x I (intensification) can be used to analyze the potential pathways to move smallholder households out of poverty and hunger. Specific options can include Genotype x Environment x Management x Market x Ht framework can be used to analyze the potential to enhance the productivity of system components and their interactions with varying production environment resulting from changing (spatial and temporal), market, population density, and agroecological conditions at different stages of system intensification across heterogeneous smallholder farms. Experimental trials based on GxExMxMxH can be implemented within targeted landscapes for analyzing interaction between system components. The Household characterisation based on resource endowments and identification of constraints to and opportunities for adoption of specific innovations will determine socio-ecological niches for sustainable intensification of smallholder farming systems.

This framework can thus be used to illustrate the demand side of the research approach. For example, pathways for sustainable intensification can target different households as follows: (i) Pathway 1 for poor-resourced farmers with limited market access and poor soil resources: this pathway relies on multipurpose crops, legumes that provide, soil cover, nutrient-enriched grain such as doubled up legumes rotated with cereals, for soil improvement through BNF, and targeted input use such as precision application of fertilizer - this a pathway that relies fundamentally on education about human nutrition, soil nutrition and agronomic practices rather than on market access as we hypothesize this group has limited ability or resources to risk thus cannot be directly linked to markets (maybe they will over time); (ii) pathway for medium resource farmers resourced farmers that relies on some combination of above, including education and tools to improve farmer decision making, to enhance nutrient and resource use efficiency, eg where fertilizer and organic inputs be used most effectively on a farm, highlighting the tradeoffs and synergies associated with investments in fertilizer (and where to target it across diverse soils and crops), weeding, livestock etc.; and (iii) pathway of SI is for better-off farmers, with market access and resource endowed access, this involves providing technologies and support to farmers to allow them to innovate and link to markets to drive sustainable intensification primarily through high value enterprises, e.g. grain legumes, livestock or fruit trees, vegetables, etc).

**Scaling out in a biocomplex and dynamic world**

Researchers recognise the complexity of farming systems. Biophysical production systems are made up of crops, pastures, livestock, soil, and climate together with inputs and outputs as well as the management system made up people, values, knowledge, resources, monitoring opportunities and decision making (Keating and McCown, 2001). Characterizing farming systems and interactions among their components is crucial to identify innovative options, and to provide insights on better targeting. To achieve this, modelling approaches will be explored. Farm-scale analytical tools that can adequately model dynamics and key interactions in a real farm will be used to analyse and simplify the complexity as well as to simulate the productivity of highly-constrained smallholder farming systems. Approaches of two bio-economic simulation models will be used to propose an integrating platform for assessing changes in system productivity at farm-scale across all project sites. Findings will be used to make forward projections of indicators and outcomes/impact indicators at scale building on the monitoring data to be collected. Two candidate approaches are: NUANCES (Nutrient Use in Animal and Cropping Systems: Efficiencies and Scales) and APSFarm (Agricultural Production System: whole farm business simulator). NUANCES (<http://www.africanuances.nl>; Giller et al., 2006; Tittonell et al., 2005, 2007) has been developed by Wageningen University and applied to explore nutrient management strategies across soil fertility gradients in Africa. APSFarm (de Voil et al., 2009) is an extended configuration of the APSIM (Agricultural Production Systems SIMulator) that has been developed by several scientists in Australia (e.g., McCown et al., 1996; Keating et al., 2003). Selected frameworks integrate modules that have been developed and applied in the highly resource-constrained, low yielding cereal/legume as well as variable climatic systems in sub-Saharan Africa (SSA). The different approaches will be presented and described.

NUANCES approach

To adequately simulate the agricultural production of African smallholder farming systems, improved understanding of their complexity and heterogeneity is unavoidable. The NUANCES approach will used to estimate the variability associated with differences in soil fertility indicators between fields within single farms using the FARSIM module (Tittonell et al. 2007). The production systems simulation models can then be parameterised for a ‘*virtual*’ farm that represents one of these groups. Household categorisation provides better understanding on how the specific objectives and endowments of different household types affect resource allocation leading to soil heterogeneity. The formulated typology will be used to distinguish patterns of soil fertility management and status among farm types. Soil variability and nutrient stocks within each group can be studied. Cropping systems can therefore be simulated within the farm for different field types. This approach has the capability to identify different classes of soil fertility that can be used to evaluate the level of soil responsiveness in terms of ‘*response*’, ‘*intermediate*’ and ‘*non-responsive*’ fields within the farm. Different combinations of crops and soils can be distinguished at the field scale for simulating the interactions occurring within the farm for aforementioned different field types.

NUANCES framework integrates a livestock module (LIVSIM, Rufino et al., 2007) that can be used to simulate livestock production and manure handling in smallholder farming systems. Trade-off analysis can also be done to estimate costs and benefits from the innovations. Bio-economic models (e.g., Affholder et al., 2010) or biophysical dynamic simulation models coupled with optimisation algorithms and objective functions representing farmer’s priorities (Tittonell et al., 2007) will be used for farm economic analysis.

APSFARM framework

The capability of the APSIM model to capture the interactions between climatic conditions, soil types, and nutrient dynamics as well as to simulate the two-way transition between flooded and non-flooded soil conditions in cereal-based farming systems in Africa will be explored. Available published papers on the application of maize, sorghum, pearl millet, rice, and leguminous crops in sub-Saharan Africa will be reviewed. The study will focus on key legumes such as common beans, cowpea, groundnut, pigeonpea, and soybean, and pastures. The different cropping systems, management practices, inputs and simulation outputs will be assessed to provide insights in the flexibility of APSIM by combining different modules in the same simulation.

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